PiFEx Propagation Experiments

Richard F. Emerson
Jeff B. Berner
Loretta L. G. Ho

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109

ABSTRACT

The Pilot Field Experiments (PiFEx) have provided considerable data (more than 1 gigabyte) on the performance of MSAT-X equipment and subsystems. These data have been used to optimize performance of the system. Data has also been collected on propagation effects using a satellite beacon operating at L-Band. Preliminary results show good agreement with earlier work.

INTRODUCTION

This paper presents an overview of the Pilot Field Experiments (PiFEx) performed under the Mobile Satellite Experiment Program (MSAT-X) at JPL. The first section is a brief history of PiFEx and plans for further experiments. The second is a discussion of some results from the Satellite 1a experiment held last August.

PiFEx: Past, Present, and Future

The Pilot Field Experiments were developed to provide an orderly transition from the development of a system architecture, and the equipment necessary to implement that architecture, to a prototype system for demonstrations and user experiments. PiFEx was started in November of 1985 with the expectation of demonstrating a major portion of the technologies under development at JPL by the first quarter of 1987. While the main thrust of PiFEx has been the performance evaluation of the equipment, it was realized that measurements of the propagation environment should be an essential part of the activity. The mobile laboratory, referred to as the Propagation Measurement Van, was designed and built to support both the engineering and propagation experiments (Emerson, 1987).

The first in the PiFEx series (Tower 1) was performed at the Wave Propagation Laboratory facility in Erie, Colorado. These experiments were primarily engineering in nature. In addition to the verification of system integration, the performance of the JPL developed Mechanically Steered Antenna and the data modulation technique were evaluated. While static tests had been performed at JPL, these were the first tests where a mobile environment approximating the satellite link was available. Even here the ability to evaluate the open loop tracking performance of the antenna, using a turn rate sensor, was severely limited. However, valuable experience was gained during this activity. A description of Tower 1 was published in the MSAT-X Quarterly series (Emerson et al., 1988).

The second PiFEx activity (Satellite 1a) was conducted on roads and freeways between JPL, in Pasadena, and Santa Barbara, California. While, again, the primary purpose was to evaluate equipment performance in a realistic environment, special attention was given to selecting sites where useful propagation data could also be obtained. The original plan was to use a signal from a Pacific Operational Region INMARSAT transponder. Scheduling difficulties precluded this. However, there was a beacon signal available on a MARISAT satellite. The level of this beacon is somewhat less (~ 4.0 dB) than desired (Parkyn, 1987 and Sue, 1987). This, combined with the low elevation angle to the satellite (~ 13 degrees), provided a test beyond the worst case limit of design. Again, the evaluation of performance of the JPL Mechanically Steered Antenna was the primary purpose of the experiment. The secondary, but equally important, purpose of the experiment was to gather propagation data under a variety of terrains and shadowing conditions using the steered antenna (Berner, 1988a). As is discussed below, data was collected for uncluttered, hill shadowed, vegetatively shadowed, and freeways with overpasses and obstructive vehicles.

The third in the PiFEx series (Tower 2) was performed, once again, at the Wave Propagation Laboratory facility in Erie, Colorado. These experiments were primarily engineering in nature, as before. In addition to the continued evaluation of the performance of the JPL Mechanically Steered Antenna, the performance of a phased array antenna developed by Teledyne Ryan Electronics was tested. A brief description of Tower 2 was published in the MSAT-X Quarterly series (Berner, 1988b).

PiFEx Tower 3, planned for July 1988, will continue to evaluate the performance of the phased array and mechanically steered antennae; of the 8 phase differentially detected, trellis encoded modulation technique (8DPSKTCM); and the 4.8 kilobit speech coders in a full duplex simulated satellite link. Additionally, some aspects of the network protocol will be evaluated.

Satellite 1b, planned for autumn, will concentrate on evaluating propagation effects and the improvement in performance that can be obtained with a directive antenna. Measurements will be made, simultaneously, of the INMARSAT Beacon signal at a fixed site and on the van using two antennas: 1) a drooping dipole (4-5 dBi, omni) and 2) each of the available directive antennas. Measurements will be made over the same terrain and at the same speed for each antenna. These experiments should provide data to enhance the understanding of the propagation effects and the potential system performance.

One of the products of the intensive experiment schedule has been the accumulation of raw data. This raw data has been recorded in several different formats depending upon the maturity of the Data Acquisition System and experiment requirements. In an attempt to make the raw data more accessible to experimenters, we have developed and are implementing an archival file format. This format will not only handle the past experiment data sets, but is extensible so that it will handle future requirements as well (Berner 1988c).

Satellite 1a

The PiFEx Satellite 1a test was conducted in Santa Barbara, California, from August 9, 1987 to August 19, 1987. The area was selected because the elevation angle to the INMARSAT satellites over the Pacific Ocean is the highest in the Southern California area and because of the proximity to JPL. Initial discussions with INMARSAT had centered around the use of the transponder, providing a signal at +26 dBW EIRP. The transponder was not available for the period selected for the experiment. However, a beacon on the MARISAT satellite was available and was used as the RF source. The beacon level is only +22 dBW EIRP. This, coupled with the lower gain of the antenna at the 13 degree elevation, required that adjustments to the MSAT-X receiver gain profile and antenna control loop parameters be made. A low noise amplifier and bandpass filter were mounted as close to the antenna as practical, between the directional coupler and the rotary joint. (Details of the JPL antenna can be found in Ref. (Emerson et al., 1988).) This added over 30 dB gain and minimized the effects of the losses in the antenna. Additionally, the bandwidth of the loop used to track the satellite azimuth was reduced. This, in turn, limited the turn rate tracking ability. This limitation affected the ratio of open to closed loop data gathered by the experiment. Propagation data gathered by the experiment was not affected.

The tilt of the antenna was also adjusted to maximize the gain of the antenna for the 13 degree elevation of the signal source. No improvement in tracking performance was noted. The impact of this change on propagation has not yet been evaluated.

The path of the experiment is given in Figure 1. Each (+) represents the start of a record of data of approximately 75 seconds. (The legends [e.g. A-5] indicate the name of the data cartridge where the data for that section of the path is stored.)

A section of the path around Santa Barbara has been expanded to show the correlation between the position data collected using Loran-C and a street map (Figure 2). The Loran is sampled every four seconds and no curve fitting was used for the representation of Figure 2. While not perfect, it is still capable of being used to correlate the terrain and shadowing effects with the received signal strength.

A short segment of received signal level data is shown in Figure 3. The data are effectively normalized by receiver limits. A 15 minute segment along the coast was used to determine an average which is then used as the normalized level for the computation of statistics. Data from the in-phase and quadrature outputs of the receiver are sampled 1000 times a second and used to compute the power level. A moving average over 10 ms was used to smooth the data which is shown as the heavier curve in Figure 3. The value of 10 ms was chosen only to verify that the processing program was working correctly. Further work is needed to define how this value should be chosen. Work is also in process to create spectra of the received signal level. This should be useful in evaluating the multipath rejection capability of the antenna.

Two segments of data approximately 15 minutes in length were selected to compute fade statistics. The first of these covered the San Marcos Pass area, a canyon area. The closest hillside was on the same side as the satellite. The second segment was along the coast line with essentially an unobstructed

view of the satellite. There is, however, some vegetative shadowing along this path. Figure 4 shows the fade statistics for these two paths. A fade depth of 0 dB corresponds to the average power in Figure 3. These curves compare favorably with the results of Vogel and Goldhirsh, Butterworth, and others (1988).

Conclusion

The PiFEx series of experiments has been successful in collecting propagation data as well as the engineering performance data. Only preliminary analysis of the propagation data has been done to date. The analysis has been primarily to verify that the processing tools developed so far are useful and correct. These analyses will also guide in the further development of analysis tools.

References

[1] Emerson, Richard F., Pilot Field Experiments, Proceedings of NAPEX-XI, June 19, 1987, Blacksburg, Virginia.

[2] Emerson, Richard F., ed., Special Issue of PiFEx Tower-1 Experiments, MSAT-X Quarterly, No. 13, January 1988.

[3] Parkyn, James, S1a Link Analysis, JPL Internal Document, September 18, 1987.

[4] Sue, Miles, Preliminary Link Budgets for PiFEx Using the INMARSAT Satellites Over the Pacific Ocean, JPL Internal Document, October 15, 1987.

[5] Berner, Jeff, The PiFEx Satellite 1a Experiment, MSAT-X Quarterly, No. 15, June 1988.

[6] Berner, Jeff, The PiFEx Tower-2 Experiment, MSAT-X Quarterly, No. 15, June 1988.

[7] Goldhirsh, J. and Vogel, W., Attenuation Statistics Due to Shadowing and Multipath from Roadside Trees at UHF and L-Band for Mobile Satellite Systems, JHU/APL S1R88U 004, February 1988.

[8] Berner, Jeff B., PiFEx Data and Archival Formats, NAPEX-XII, June 10.1988, Syracuse, NY.

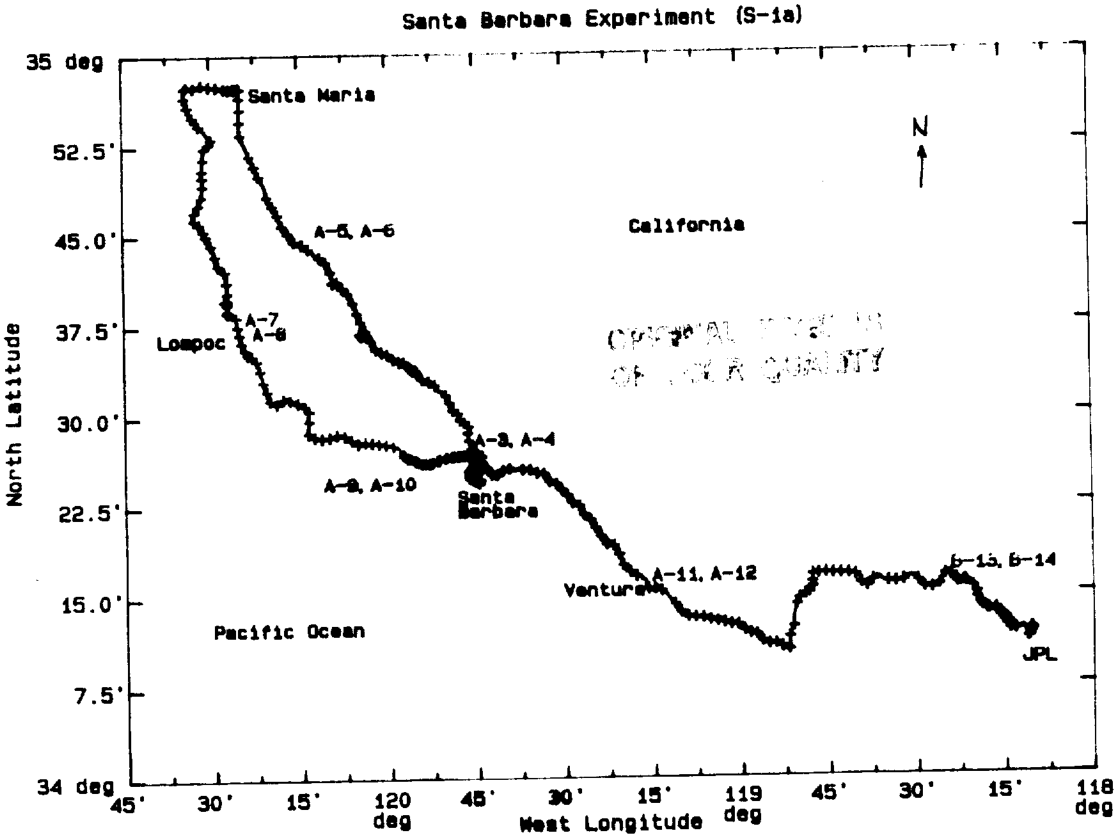

Figure 1 Satellite 1a Experiment Path

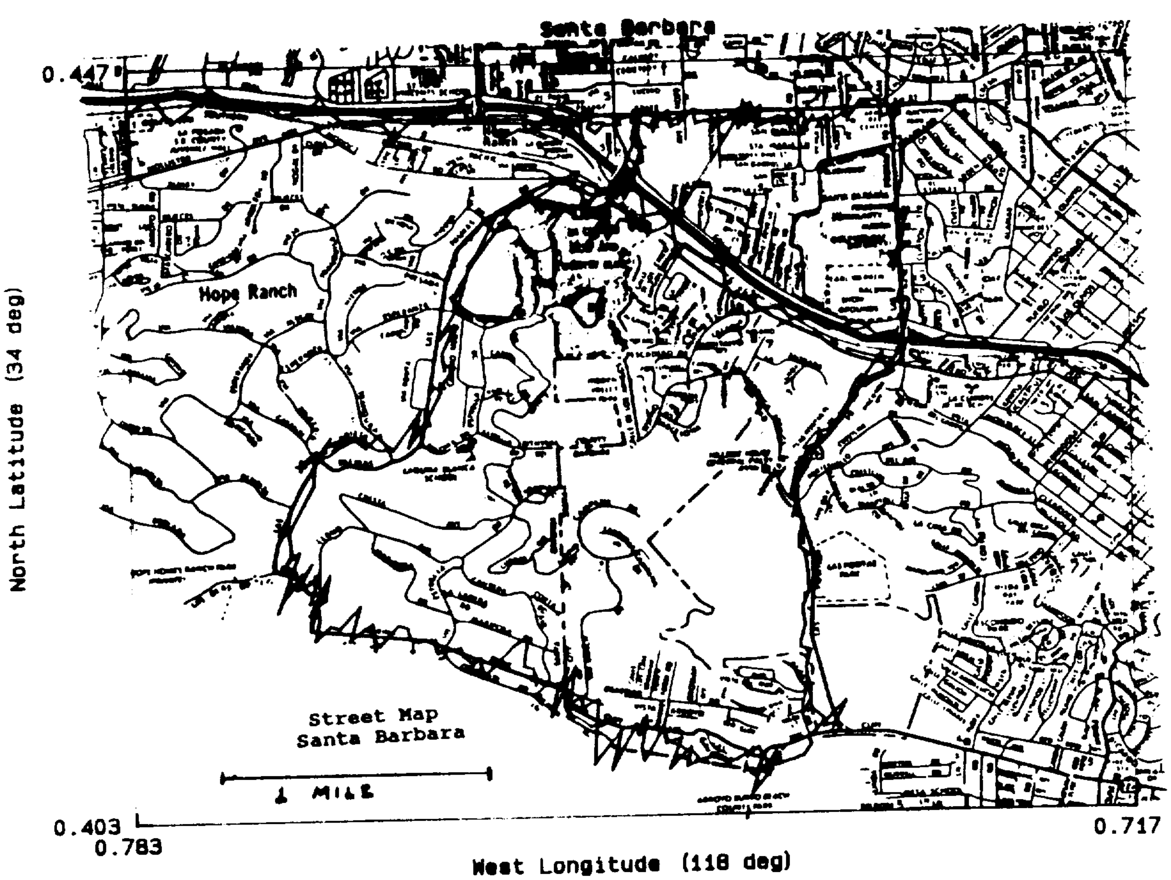

Figure 2 Map and Loran Data Comparison

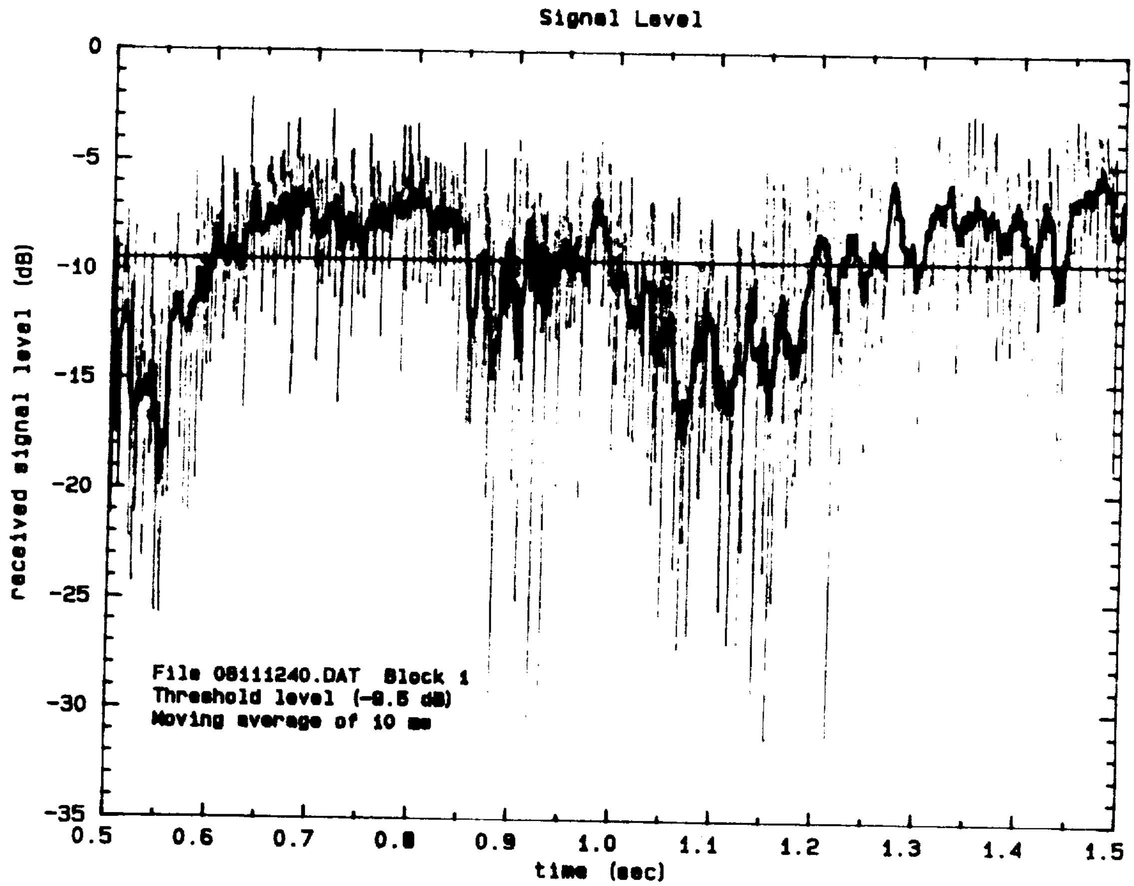

Figure 3 Received Power vs Time

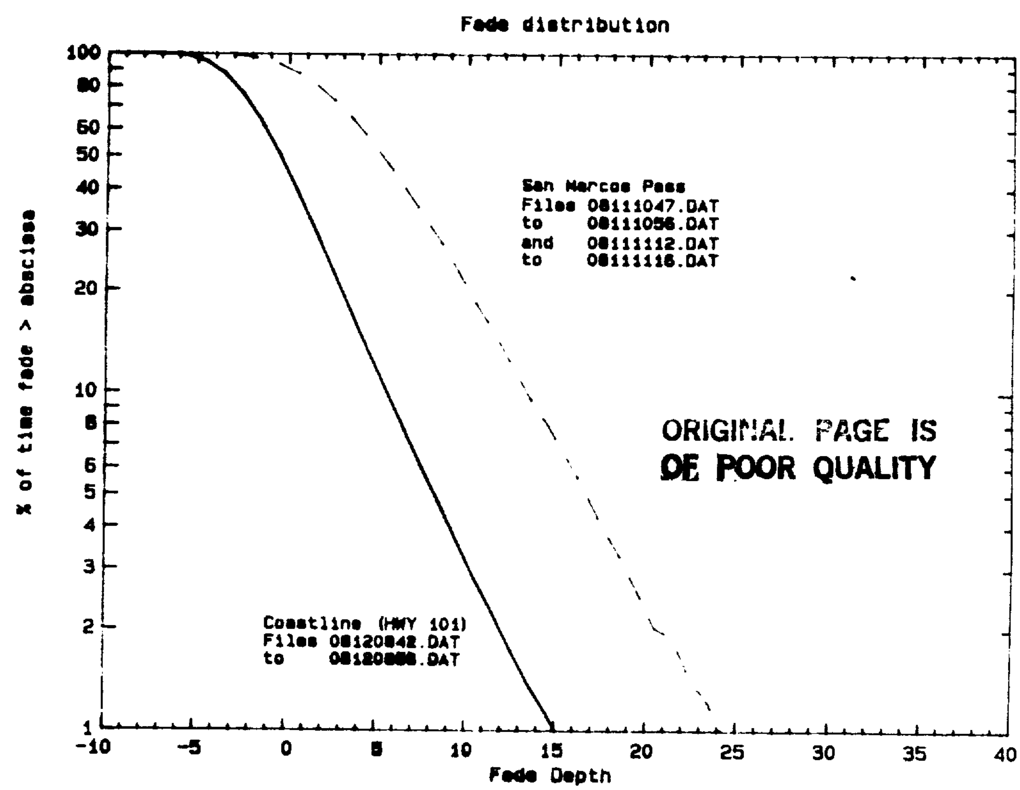

Figure 4 Fade Depth Distribution